Aerosol Effects on Liquid-Water Path of Thin Stratocumulus Clouds

Contributors
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Research Highlight

Thin clouds with mean liquid-water path (LWP) of ~ 50 g m-2 cover 27.5% of the globe and thus play an important role in the Earth's radiation budget. Radiative fluxes at the Earth's surface and top of atmosphere (TOA) are very sensitive to the LWP variation when the LWP becomes smaller than ~ 50 g m-2. This indicates that aerosol effects on thin clouds can have a substantial impact on the variation of global radiative forcing if LWP changes.

This study examines the aerosol indirect effect (AIE) through changes in the LWP in three cases of thin warm stratocumulus clouds with LWP Z01; 50 g m-2. We use a cloud-system resolving model (CSRM) coupled with a double-moment representation of cloud microphysics. Intensified interactions among the cloud droplet number concentration (CDNC), condensation and dynamics at high aerosol number concentrations play a critical role in the LWP responses to aerosol increases. Increased aerosols lead to increased CDNC, providing increased surface area of droplets where water vapor condenses. This increases condensation and thus condensational heating to produce stronger updrafts, leading to an increased LWP with increased aerosols in two of the cases where precipitation reaches the surface. In a case with no surface precipitation, LWP decreases with increases in aerosols. In this case, most of precipitation evaporates just below the cloud base. With decreases in aerosols, precipitation increases and leads to increasing evaporation, thereby, increasing instability around cloud base. This boosts updrafts and thus condensation, leading to larger LWP thereby compensating for reduced interactions among CDNC, condensation and dynamics at lower aerosol concentrations. The results from these three cases with thin clouds are at odds with those from comparatively thick warm clouds (with LWP > ~ 70 g m-2), where the decreasing sedimentation of hydrometeors is known to determine the LWP response to aerosol increases. Our results suggest that different approaches to parameterization of aerosol-cloud interactions for thin and thick stratiform clouds need to be considered to better assess aerosol effects on clouds and thus climate.

The second AIE is known to be entangled inextricably with environmental conditions such as the humidity, large-scale subsidence, sea surface temperature (SST), and surface sensible and latent heat fluxes [Jiang et al., 2002; Ackerman et al., 2004; Guo et al., 2007]. Hence, aerosol-cloud interactions in thin clouds may vary with these environmental factors and this needs to be addressed in future studies. Nevertheless, this study demonstrates that mechanisms through which aerosols affect the LWP in thin clouds can be different from those in cloud systems with comparatively higher LWP at least for three cases studied here. This study suggests that different approaches to the LWP variation with aerosols are needed for thin and thick stratiform clouds for better parameterizations of aerosol-cloud interactions in climate models and, thus, the estimation of changes in radiative forcing by aerosol indirect effects.

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Reference(s)
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Working Group(s)
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